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The Kolamba Rice of the North Konkan and its Improvement by Selection

BY

R. K. BHIDE,

Crop Botanist to Government of Bombay, Poona

AND

S. G. BHALERAO, B.Ag.

Superintendent, Rice Breeding Station, Karjat

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S. G. BHALERAO, B.Ag.,

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(Received for publication on 11th December, 1926.)

I. Introduction.

The *Kolamba* variety of rice is the most important of all those grown in the North Konkan in the Bombay Presidency and the neighbouring country not very high above sea level. The chief centre of its cultivation is the Thana and Kolaba Districts. The adjoining parts of Surat, Ratnagiri, Ahmednagar, Satara and Poona take an almost negligible share in the cultivation of the variety. The actual acreage under this rice is not easy to determine. An approximate idea can, however, be formed. The total rice area in the Thana and Kolaba Districts is nearly 600,000 acres, and in the neighbouring districts it is about 200,000 acres.[1] In this area about fifteen different types of rice are grown, many of which are, however, inferior, and are only cultivated where the better kinds will not grow. Of the superior types, the authors estimate that at least 200,000 acres are covered by the *Kolamba* rice, and its cultivation is rapidly spreading wherever it can be grown.

Kolamba rice is said to owe its name to a kind of prawn called *Kolambi* or *Kolambya*, which is generally eaten with this type of rice by the fish-eating population. The rice may be said to be somewhat lacking in flavour which is given to it by the prawn in question. This theory suggests that the variety originated near the sea coast, and this is in accordance with other indications. It appears that until less than a generation ago, except near the coast, the varieties chiefly grown in what is now the *Kolamba* area were those known as *Patni* and *Tawsal* which have much coarser and less translucent grains. The *Kolamba* variety, however, became popular in and near Bombay, where it commands a much higher price than the other

[1] Season and Crop Report of the Bombay Presidency, 1923-24.

coarser and inferior sorts. It has now spread right up to the foot of the Western Ghats, but has not gone much beyond them. The area now occupied contains about eight sub-varieties of *Kolamba* rice. The differences between them will be described later.

As has already been stated, the cultivation of the variety under discussion is steadily increasing, and there is a great traffic in it to Bombay. There are numerous mills which devote themselves to hulling and polishing it, particularly in the Thana District. The finished product is often termed *Kalyan* rice, as much of it is sent out from this centre. It is largely consumed by the middle and upper class population in Bombay and its suburbs, and in Gujarat, Baroda and Kathiawad. To the cultivators, it is almost entirely a money-making crop, with a high cash value. As for their consumption, they prefer coarse types of rice which can be purchased fifteen or twenty per cent. cheaper but which are better in nutritive value. In place of *Kolamba*, they often use Rangoon rice which is generally cheaper even than the local coarse rices. The landlords often make it compulsory on their tenants to grow *Kolamba* rice, especially where there is the system of share rents, as this brings a high price in Bombay.

Kolamba rice is very fine, with white translucent grains. These are also hard and flinty. Though this rice has no smell or flavour, its slender and fine grains retain their general form when cooked, and do not turn into a sticky mass as the grains of the softer and coarser rices do. It also takes a fine polish in the mills, and presents a crisp and inviting appearance when served as a dish. The importance of fineness and crispness is so great that the richer classes often prefer it even to some of the scented rices like *Ambe Mohor* and *Kamod*. The former of these is not so translucent and the latter not quite so fine as *Kolamba*.

Kolamba rice is, moreover, the chief type exported from the Thana Disrictt and is in demand from other parts of India, (Burma, Madras, Sind, Gujarat, Kathiawad) and from other countries (Arabia, Persia, East Africa, Natal, Zanzibar, etc.). In the latter case, it is taken apparently for the use of the Indian population. The actual exporting centres are Bombay, Bhiwandi and Panwel, and direct cargoes go even from the latter places as far as Kathiawad.

The average yield of the rice crop per acre in the North Konkan may be taken at about 2,000 lb., and the crop is very regular and certain. What with high rents and high costs for labour, the margin of profit to the actual cultivators, however, is not very great, and as a result, it is important that the yield per acre should be increased. This can, of course, be attained by more intensive cultivation and manuring and also by the selection of types of seed which give a higher yield per acre. The former method of increasing the produce per acre does not affect us here, but the latter method has been successfully followed in the work to be described in the present paper. The basis of the selection undertaken has been bulk samples received from the cultivators of the *Kolamba* area, which have proved themselves mixtures of widely differing types of very different economic value.

PLATE 1.

1. Showing the method of recording plant to plant measurements and observations, and of

2. Showing all tillers reaching nearly the same height, and the erect nature of the plants.

The work to be described was commenced in 1918 by the late Mr. H. M. Chibber, but he, unfortunately, did not live to see the results of his labour. After his death, the work was continued by the present authors. When commenced, it was carried out at two centres, namely Alibag in the Kolaba District, and Jambul in the Thana District. In 1919 the whole was transferred to a rice research station established at Karjat in the Kolaba District and the present authors have carried it on at this centre since 1921. This centre is very representative of the *Kolamba* rice tract. The basis of the selections were bulk samples collected in large number in Thana, Surat and Kolaba in 1918, 1919 and 1920. The methods used in growing the samples were those of the district with only such deviations as were needed for experimental accuracy, or for facility in uniform transplanting and even spacing. Thus, single plants alone were used for transplanting, and they were put in straight lines with enough space on each side for easy movement for observation. The plants intended for seed purposes have always been bagged (Pl. I, 1) since 1920 to maintain their purity by preventing natural cross fertilization.

From the bulk samples grown in 1918, 210 plants were selected on the basis of morphological characters supposed to have a more or less direct bearing on high yield and earliness. Rough yield comparisons have been carried on since 1919. They were at first based on the produce of an equal number of plants in the different cultures. The number of plants forming the basis of comparison was 200 in 1919 and 1,200 in 1920, in which year each culture was repeated six to nine times over the experimental area. On working out the yield comparisons of the 1920 crop, ten samples gave promise of being useful. Of these, eight were promising in yield and fineness of grain and two were very early in ripening though coarse in grain size. The purity was not, however, certain and an elaborate programme was adopted in 1921 and 1922 to determine and maintain the purity of the types, and to study them closely under uniform conditions in the various cultures. These plans involved detailed notes on the various cultures, regarding special features, and plant to plant measurements, weights and counts in the field and in the laboratory of all the important characters of the different types. This has enabled a very high standard of purity to be reached among the types, while numerous replications of every important selected type with the usual cultivators' seed have given the possibility of very accurate comparison of yield.

II. The Kolamba rice : the material for selection.

The *Kolamba* rice is known by three names in different parts of the tract where it is grown. These are (1) *Kolamba*, the most common name, and one recognised everywhere, (2) *Rata*, or *Tambada*, a name chiefly used in the Thana District, and chiefly, if not exclusively, employed to denote the reddish husked, comparatively coarse and somewhat inferior types generally and (3) *Bhurya*, which is also chiefly used in the Thana District, and specially denotes the pale husked fine superior types, also known as *Zinya*.

The above are names in common use. But there are a number of well recognised agricultural types, distinctly separated by the growers of the variety, whose characteristics are noted below :—

1. *Mahadya.* This is a tall type with a long panicle carrying a comparatively small number of branches and a smaller number of large sized grains. This is at present grown in certain parts of the Kolaba District only. Its cultivation is steadily decreasing on account of its coarseness and slight lateness in ripening.

2. *Ghudya.* This type is somewhat finer. Its panicle is rather compact, for which reason it is called *Ghudya* or cluster-grained. The husk is reddish in colour, whence it is also classed with the *Rata* or *Tambada* types, both of the terms meaning red. This can be grown with success on soils of medium fertility. It is reported to yield better than the *Zinya* types, to be mentioned next. But it commands a slightly lower price in the market for the reason of its comparative coarseness. This type is generally late and takes about 150 days for ripening.

3. *Garwa Zinya.* This is the finest type in cultivation and in the market. The colour of the foliage is light green, and of the ripe husk pale yellow. The grain is rather short, pronouncedly slender, and the tips of the kernel are pointed. This is said to require a balanced condition of the soil as regards manure. In fields with ordinary fertility it yields rather poorly, whereas in fields that are extra rich it turns to leaf and is spoiled badly. It ripens about a week earlier than the *Ghudy* type. The husk fits the kernel rather loosely and is easily separable. It also shows a smaller proportion of husk to kernel when compared with other types, and for all these reasons it commands a higher price in the market.

4. *Halwa Zinya.* This ripens about a fortnight to three weeks earlier than the *Garwa Zinya* described above. It can be grown with success on lands which are extra rich in fertility and where other types would invariably run to leaf. Thus this type does not suffer from heavy manuring, but under such conditions yields a fairly heavy crop, matching the late type in the matter of yield. It requires, however, very timely harvesting, otherwise it suffers from shedding of grains in the field and their breakage in milling. The grain is longer and more slender than that of the *Garwa Zinya* and consequently may command even better prices than the latter.

5. *Halwa Ghudya,* also called *Tokadya.* This is a reddish husked type comparable to the *Ghudya* described under No. 2 above. The only difference between the two is the time of maturity, the *Halwa* type maturing about two or three weeks earlier than the *Garwa* type.

6. *Korkadya.* This type may be described as almost similar to the *Ghudya* type. It is doubtful if it is at all distinct from it. It may differ in the time of maturity, as the cultivators say that they grow it to distribute their harvesting over a longer period. In this type the grain colour is just the same as that of *Garwa Ghudya,* but in size and shape the grain is rather short and blunt at the ends, besides it matures about ten days earlier than the *Garwa Ghudya.*

7. *Kachanya.* This is similar to *Korkadya* except that its grain is slightly thinner and the two ends of the kernel are slightly more pointed.

8 and 9. *Kasadya and Javarya.* These two types are particularly early. They ripen about one month in advance of other types. In grain size they are pronouncedly coarse and have comparatively thick kernels. They are grown on high lying lands. They are a source of ready money to the cultivator in the early part of the season, as they have a ready market. The dealers purchase them as they are cheap for mixing with the costly superior varieties.

Defects of the Kolamba rice crop. As has already been noted, this valuable commercial variety of rice is a recent introduction, and hence its defects as compared with other types are well recognized and often discussed. The cultivators complain that fine grains are generally associated with low yield, and that in certain seasons particularly there are many unfilled grains on the heads. Further, where the fields are very rich, the crop is said to run to leaf and to produce many uneven and unproductive tillers, so that the ripening is uneven. Again, it is said often to have weak straw, and hence to be apt to lodge so that the grain is damaged. In addition to these defects, it is liable to shed the grain badly if slightly over-ripe and to be very sensitive to a shortness of water during the growing season. It is also liable sometimes to the attacks of the stem borer which causes many earheads to remain unfilled.

The miller who husks and polishes the grain complains of *Kolamba* rice that it is not uniform in size of grain and hence does not polish well, and further that it is apt to much breaking of grain during the milling operations. This means, of course, that the *Kolamba* rice is not even, as brought to the mills, so that the coarser grains are broken and finer ones escape the polishing process.

It is obvious from these complaints that any selection must take account of the defects indicated, and that the aim must be to obtain an even type suitable, as regards fineness, time of ripening and high yield. It should be strong in straw, little affected by excess of manure or by shortage of water, and should not shed the grains seriously if slightly over-ripe. It should also resist the attack of the stem borer.

The need of such an even type with these characters is recognised in the *Kolamba* growing areas. The better cultivators take a good deal of pains to reserve what they consider as the best of their seed for cultivation, though this best may often be so only in appearance. Their methods of selection are two. One consists in collecting such grain as drops down near the stack while the sheaves heaped there are being removed to the threshing yard, and using this for seed purposes. The idea in this case is that the seed that drops in this way is likely to be heavy and well developed and hence better suited for sowing purposes and for securing a good yield. The other method consists in selecting large and heavy earheads from the sheaves in the threshing yard for seed purposes. Both these methods are obviously used with the idea of getting high yield either by the use of heavy grain for seed, or by obtaining heavy earheads irrespective of the other important characters of

the plant. Owing to the frequent occurrence of cross-fertilisation in this region and to the fact that the types in cultivation are, hence, more or less impure, the effect of these methods in producing pure breeding plants with large outturn and other desirable characters is very limited. Selection of the plant in the field, based on its various valuable inherent characters including tillering, is not, in the authors' experience, carried on in the *Kolamba* area. The limited selection adopted has, apparently, resulted in obtaining a predominance of types either with extreme fineness of grain or peculiar colour of husk which are found in certain parts of the area. Thus it has resulted in some cases in an improvement of quality rather than in yield.

The ideal type of Kolamba rice. Considering the conditions of growth and the demand of the market, it is possible to indicate in some detail the type of plant which selection should aim to obtain.

From the morphological point of view, the ideal *Kolamba* rice should have a medium height and a thick erect culm. Tall and thin stemmed plants, and plants with a bending and spreading habit are easily swayed by the wind and are hence more likely to lodge. Leafiness should only be moderate, as excessive development of leaf would be very objectionable in highly manured fields near village sites or forest areas. A strong tillering habit is an advantage, provided the tillering is rapid and the earheads on the tillers reach about the same height as the main panicle and ripen about the same time as the latter. Otherwise, there is unevenness in ripening, and loss of quality and yield. This is a matter of special importance in a somewhat free tillering variety like *Kolamba*. Uneven ripening means shedding of the grain in the earlier formed earheads, or a large amount of breakage in milling of the unripe grains.

The leaves of the plant should be glabrous, as there seems to be some correlation between hairiness of leaf and coarseness of grain. The peduncle should be rather short, as long peduncles are likely to break and to prevent the proper development of grain. The panicle should be long, large, compact and heavy, and have few or no sterile grains, while the grains themselves should be fine. Awnless types are to be preferred to awned ones.

The ideal type of *Kolamba* rice for the Thana and Kolaba Districts should mature within about 140 days. In the strains so far found very early maturity means poor production and very lateness is risky owing to shortage of water.

The type selected should be easily hulled, and should have a white kernel, so as to cause less labour in polishing and less waste in the finished product.

III. Botanical description of the Kolamba rice and its variations.

The *Kolamba* rice belongs to *Oryza sativa* var. *communis* (Kœrnick) sub-variety *media*. The spikelets are elongated, their length being more than three to four times the breadth. In shape they are sub-linear or narrowly elliptic-lanceolate, the palea being nearly straight and the flowering glume only slightly convex at the

back. The *Kolamba* plant is free from anthocyanin pigment, *i.e.*, there is no reddish or purplish colour in the sheath or any other part of the plant. It is free from awns also. The husk when ripe is pale yellow to rusty reddish brown. The kernels or grains are generally translucent and flinty, and more or less white in colour. They are devoid of smell.

There is a great deal of variation in almost all the characters of the *Kolamba* variety. It can be divided into a number of more or less distinct botanical types. As mentioned before, several types are already known to the cultivators and the people at large and a considerable number of sub-types of an elementary nature have been separated and maintained at the Rice Breeding Station at Karjat.

Thus it will be seen that the name *Kolamba* is rather loosely applied to a large number of strains which are distinct from each other. The main points, however, in which they resemble each other are (1) the slenderness of the spikelets and grains, (2) the linear to elliptic-lanceolate shape of the spikelets and grains (3), the reddish or brownish yellow colour of the husk, (4) the translucence of the grain, (5) the flintiness of the grain, (6) the whitish colour of the grain, (7) freedom from anthocyanin pigment throughout the plant, (8) absence of awns and (9) lack of smell.

Classification of the various characters. In order to make a detailed study of the various characters of the *Kolamba* variety as a whole it would be convenient to divide them into two classes, *viz.*,vegetative and reproductive. These will, therefore, be dealt with separately.

It may be stated here that the characters described below have been observed in pedigree cultures of the original selections both in the laboratory and in the field for more than three successive generations, and though they are subject to slight fluctuation owing to conditions of nutrition, growth, etc., they may be safely taken as the expression of hereditary qualities of the various cultures.

Vegetative characters.

Germination and rate of growth. In folds of wet blotting paper the seeds of the different strains take from 30 to 45 hours for the husk to rupture and for the radicle to emerge. In field conditions the plumule shoots out in the form of a needle within about 72 to 96 hours from sowing if the seed beds are properly wetted by rain. The first leaf unfurls within 150 to 170 hours. Two of the authors' strains Nos. 79 and 110, which have coarse grains and mature very early, that is to say 30 to 35 days in advance of the majority, generally showed a quicker unfurling of the leaves and had a stronger growth in the first week. But there cannot be said to be a very appreciable difference in the time taken by the different strains to germinate and for their early growth. Some of the very late strains also, such as Nos. 103 and 104 which mature about 10 days later than the late strains, do not seem to be slow in their germination and early growth. On the other hand, No. 184, another very

early strain, but with finer grain, is not so vigorous in its growth as other early types like Nos. 79 and 110. There is therefore no reason to suppose that the early maturing strains have necessarily a much quicker and the late ones a slower rate of growth in their seedling stage or for the first three weeks or so. Their behaviour on resuming their growth after transplanting, *i.e.*, from August 1st, is however remarkable, inasmuch as the very early ones show a markedly greater rapidity in attaining the limit especially of their height, and perhaps, though less markedly, in producing tillers and respective leaves. This will be seen clearly from the three Tables given below :—

TABLE I.

Showing the rate of growth in height of the different strains of Kolamba as indicated by the average heights of plants upto the joint of the first leaf from top, measured at successive one week periods in cm.

Periods	STRAINS										
	VERY EARLY		INTERMEDIATE		LATE					VERY LATE	
	No. 79	No. 184	No. 153	No. 164	No. 32	No. 35	No. 39	No. 42	No. 121	No. 103	No. 104
August 1, 1924 . . .	16·6	18·0	16·8	15·6	16·0	14·4	15·0	13·8	15·2	14·4	16·4
,, 8, ,, . . .	18.4	20·2	18·0	17·8	18·2	17·0	18·0	15·6	18.6	17·2	17·6
,, 15, ,, . . .	24.4	23·8	20·4	19·4	18·8	18·8	20·0	17·2	21.2	19·2	19·4
,, 22, ,, . . .	32·4	28·0	22·4	21·2	21·6	20·0	21·2	18·4	22·8	20·8	20·8
,, 29 ,, . . .	50·8	40·0	26·4	26·8	26·0	26·0	26·4	25·2	26·8	25·6	24·8
September 5, 1924 . . .	77·8	61·0	32·0	28·2	27·2	27·2	30·2	26·0	31·2	28·4	26·6
,, 12, ,, . . .	100·0	77·6	36·0	33·0	31·2	31·4	35·6	28·6	35·0	31·0	29·8
,, 19, ,, . . .	101·2	78·8	47·8	44·4	37·4	38·0	41·6	31·4	37·2	33·0	31·2
,, 26, ,, . . .	..	..	74·6	71·0	46·8	49·2	50·0	39·2	45·4	39·0	36·2
October 3, 1924 . . .	..	..	98·6	97·2	64·2	68·4	84·0	53·4	57·2	47·2	41·4
,, 10, ,, . . .	..	..	..	..	88·8	90·4	102·2	77·0	80·2	60·2	50·4
,, 17, ,, . . .	..	..	..	..	..	..	..	115·8	144·8	75·8	72·6
,, 24, ,, . . .	..	..	..	..	..	..	..	..	148·0	110·2	115·2

The very early strains show a very rapid progress in attaining the limit of their height.

TABLE II.

Showing the rate of growth as indicated by the average number of tillers per plant produced by the different strains of Kolamba at successive one week periods.

Periods	STRAINS										
	VERY EARLY		INTERMEDIATE		LATE					VERY LATE	
	No. 79	No. 184	No. 153	No. 164	No. 32	No. 35	No. 39	No. 42	No. 121	No. 103	No. 104
August 1, 1924 . . .	1·4	1·0	1·0	1·4	1·0	1·0	1·0	1·0	1·0	1·0	1·0
„ 8, „ . . .	2·4	2·0	2·6	2·4	1·2	1·6	1·8	1·7	1·4	1·6	1·8
„ 15, „ . . .	4·0	3·2	4·4	4·4	3·0	3·4	4·2	3·5	2·6	3·4	3·6
„ 22, „ . . .	5·8	5·6	8·2	7·2	5·8	4·8	6·6	6·0	4·4	5·4	6·4
„ 29, „ . . .	8·2	6·2	9·8	8·2	8·2	5·4	7·2	6·7	6·2	7·2	7·6
September 5, 1924 . . .	8·2	6·8	10·4	8·6	8·2	6·0	7·8	7·0	6·4	7·0	8·0
„ 12, „ . . .	8·4	6·8	10·4	8·8	8·2	6·6	8·0	7·5	6·6	7·0	9·4
„ 19, „ . . .	8·6	6·8	10·4	9·0	8·2	6·8	8·0	8·0	6·8	7·6	10·9
„ 26, „ . . .	8·6	6·8	10·4	9·2	8·4	6·8	8·0	8·0	6·8	7·6	10·2
October 3, 1924 . . .	8·6	6·8	10·4	9·2	8·4	6·8	8·0	8·0	6·8	7·6	10·2

The very early strains show better progress in this respect for the first three weeks or so, but later on the other strains are seen to make up the growth as the early strains are generally poor in tillering.

TABLE III.

Showing the rate of growth indicated by the average number of leaves per plant including all the tillers produced by the different strains of Kolamba at successive one week periods.

Periods	STRAINS										
	VERY EARLY		INTERMEDIATE		LATE					VERY LATE	
	No. 79	No. 184	No. 153	No. 164	No. 32	No. 35	No. 39	No. 42	No. 121	No. 103	No. 104
August 1, 1924 . . .	5·8	4·6	5·2	5·2	4·8	4·6	4·4	4·6	4·4	4·6	4·4
„ 8, „ . . .	9·6	7.2	9·4	7·8	5·4	7·6	8·0	3·3	6·6	7·0	7·2
„ 15, „ . . .	16·2	11·6	16·0	15·0	11·8	12·4	14·0	11·8	10·2	12·4	12·2
„ 22, „ . .	24·0	19·8	27·0	23·4	20·4	20·2	21·6	20·0	16·6	20·2	21·0
„ 29, „ .	31·4	23·8	36·2	29·4	27·4	25·2	29·0	25·2	22·8	27·0	27·4
September 5, 1924 . . .	35·6	28·4	45·8	37·0	37·0	32·6	35·8	32·0	28·0	34·4	36·2
„ 12, „ . . .	36·4	29·2	50·4	40·2	42·6	36·4	37·4	37·0	32·2	38·4	43·0
„ 19 . . .	36·8	30·6	56·6	48·6	44·0	40·0	43·2	40·2	35·8	43·0	49·6
„ „ . . .	37·8	33·8	63·6	56·0	54·6	52·8	57·2	48·8	46·6	53·0	55·2
October 3, 1924 . . .	..	..	64·6	57·4	59·4	55·2	59·6	51·0	54·4	56·0	62·4
„ 10, „ . . .	..	..	..	..	59·6	55·8	..	51·8	55·6	60·4	69·0
„ 17, „ . . .	..	..	..	..	..	..	..	..	56·8	61·4	74·0
„ 24, „ . . .	..	..	..	..	..	..	..	..	..	..	..

The very early strains show better progress in this respect for the first four or five weeks, but later on the other strains make up the growth for reasons already given under Table II.

Tillering power. This character is of considerable economic importance as it is closely connected with the yield finally obtained. The rice plant begins to tiller within about fifteen days from sowing, provided the seeds are not sown very deep and thickly. Tillering is shown more markedly by certain strains than others even under uniform conditions of space and plant food. Tillering often varies with the total length of time required for maturity in the *Kolamba* variety, the early strains being poor and the late ones richer in tillering.[1] (Table IV). In another variety called *Patni*, also grown in the Konkan, however, which is as late as the late *Kolamba* types, the tillering is much poorer. But the grains in that variety are far coarser as compared with *Kolamba* and the earheads are also large and heavy, so that this variety seems to utilize the food materials absorbed in producing larger earheads and grains and not in producing numerous tillers. Late maturity and high tillering are, therefore, not necessarily correlated in *all varieties.* In comparative trial plots the mean tillering of the very early *Kolamba* strains, taking 115 days to mature, was five per plant transplanted at eighteen inches by nine inches apart, whereas in the very late strains taking 160 to 165 days it was as high as 14 when the plants were similarly spaced. But leaving aside these extreme periods of maturity the mean tillering of a large number of strains maturing within 135 to 150 days varied from 7·7 to 11·2 per plant in 1922, spaced in the way described.

Tillering also continues to a variable period in the life of a plant. The result is that in certain strains there is a variable number of unproductive tillers which on account of their very late development fail to produce panicles or well developed grains, and at the most only add to the straw. This number of sterile tillers varies from 0·3 to 2·7 per plant on an average in the different strains under conditions mentioned above. The percentage of sterile to fertile tillers varies from 7 to 22 in the different strains. This feature of continued and late tillering is objectionable but can be checked by planting closer, together, whereby the production of such late tillers would be checked and the energy of the plant utilized for the production of more grain.

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[1] Jacobson, H. O. Correlative characters of the rice plant: *Philippine Agricultural Review*, Vol. IX, page 115.

Thompstone, E. Some observations on Upper Burma Paddy *Agri. Jour. of India*, Vol. X, pp. 36-37.

TABLE IV.

Showing total tillering in the different strains varying more or less according to days to maturity.

Strain No.	1921	1922	1923	1924
Very early 79	8·4	5·02	4·61	6·79
Intermediate . . . 153	..	11·20	8·70	9·39
,, . . . 164	..	10·52	7·79	7·87
Late 32	14·90	9·70	8·78	9·51
,, ... 35	13·10	7·70	7·68	8·73
,, ... 42	11·62	9·90	9·80	10·52
,, ... 121	..	9·06	..	7·52
Very late 104	..	14·10	10·57	11·30

A closely related feature is the height which the successive tillers attain in a plant. In certain strains all the tillers may reach nearly the same height, by the time the panicles are mature, (Pl. I, 2), whereas in others the mother culm grows taller than the other tillers which individually reach a variable height. The latter feature is undesirable as it entails greater unevenness in the size of earheads and in maturity and the consequent loss of grain. These defects seem to be associated with very profuse tillering.

Another noticeable feature is the angle made by the different tillers with the mother culm and with each other. In certain strains the tillers are all nearly erect and the bunch is a close compact mass forming a narrow inverted cone, whereas in others they spread a good deal and the shape of the bunch is like an inverted cone with a wide angle. The latter strains in the authors' experience are more likely to lodge.

Colour tint of the foliage. This is a fairly constant feature of the various strains of *Kolamba* rice. It can be clearly seen as a mass effect in the field within about ten or fifteen days after sowing. It varies from light to yellowish green to medium or dark grayish green in the different strains. Although there are fluctuations due to space, food supply, etc. and though the better nourished plants are darker in colour, still the relative values of the different strains remain nearly the same under uniform conditions. Strain No. 223, exceptionally, however, has rather a pale yellowish colour just a few days after germination, but later on the colour becomes

more dark by exposure, so that the tips of the leaves are darker than their bases in the early stage of the seedlings. There seems to be some evidence, which, however, requires further confirmation, that the lighter coloured strains require a slightly lower temperature for flowering than the darker coloured. Thus while the former had many of their flowers open at 80° F., the latter commenced to open at 84° F. only. Similarly as the day advanced and the temperature rose at 11-30 A.M. to 86° F., the latter showed full flowering but the former only to a very small extent.

Plant height. The height of the mature plant in the different strains varies considerably even under closely similar conditions, the range being from 110 to 170 cm. when measured from the surface of the soil to the tip of the panicle straightened out. The measurement should, of course, be made on the mature plant only, as the early strains put forth their culm earlier.

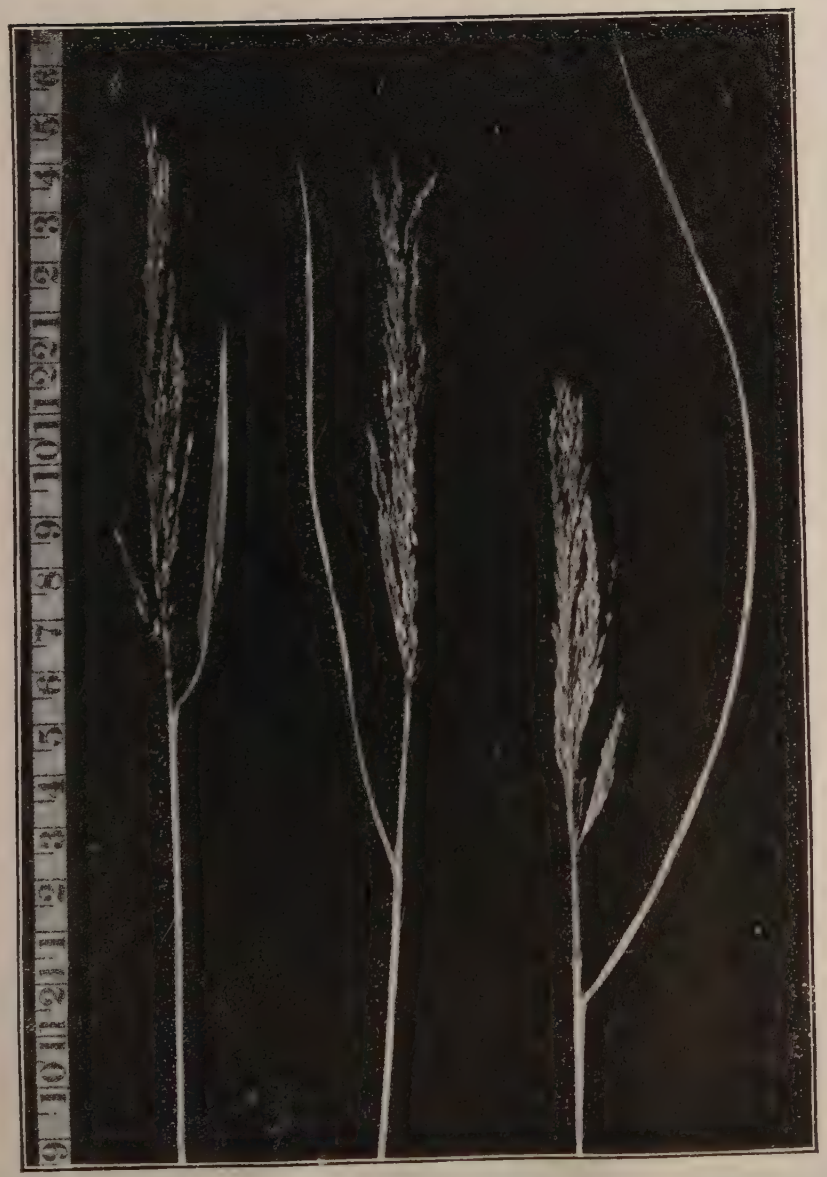
Thickness of the culm. This has been measured at the middle of the first internode above the ground. It is again a rather variable character being greatly influenced by food supply, the range being from 6·5 to 7·7 mm. in diameter. There does not seem to be any correlation between the thickness of the culm by itself and the standing power of the plant at maturity.

Number of internodes or leaves. This is a character of relative stability though it varies according to the time of maturity of the strain. In the very early strains the number of internodes or leaves is about ten to eleven including the extremely compressed ones just below or at the ground level. But in the very late strains it is eighteen or nineteen. The following table shows the number of internodes or leaves on the main culm in different strains :—

TABLE V.

Showing the number of internodes or leaves on the main culm.

Strains	Number of internodes or leaves
Early strains—	
No. 79	10—11
No. 184	10—11
Intermediate strains—	
No. 153	14—15
No. 164	14—15
Late strains—	
No. 32	16—17
No. 35	16—17
No. 39	16—17
No. 42	16—17
No. 121	16—17
No. 104	18—19



1. Showing panicles with different flag lengths as compared with the tip of the panicle.

2. Showing panicles of the *Kolamba* rice in flower.

The length of the flag (or the Uppermost Leaf). The range of variation in this respect is from 23 cm. to 44 cm. when measured from the ligule to the tip of the leaf. In certain strains the flags are generally large, while in others they are comparatively small. The flag is often a good index of the size of the leaves of the plant in general.

The breadth of the flag. The range in this respect is from 1 cm. to 1·5 cm. when measured at the widest part, some strains being proportionately broader-leaved than others.

The flag is generally shorter than the two or three leaves next below, but it is generally the broadest leaf of all. With reference to the tip of the main panicle the tip of its flag may go higher in some strains, reach about the same level in others, or remain shorter in the rest (Pl. II, 1). Its size and the position of its tip are slightly affected by the nature of the soil and the nutrition of the plant. In rich soils the flags and the leaves are longer and broader, whereas in poor soils they are shorter and narrower. The length of the peduncle, to which reference will be shortly made, is also partly responsible for the fluctuation regarding the position of the flag-tip, as it is also affected by soil conditions. But even apart from this, the position of the flag with reference to the tip of the panicle is a fairly constant strain character. As maturity advances, the flag generally droops more or less, but in certain strains it has been found to maintain an almost erect position to the last. This erect position of the flag is found very often to be associated with standing power or strength of straw. It is a very distinguishing feature of certain strains, as in Numbers 8, 164 and 104. In certain other strains the flags assume a more or less horizontal position or are inclined downwards. Such strains have a tendency to lodge as in Nos. 153, 32 and 39. In certain strains the tips of the flags are a little lighter green in colour than the lower part and look somewhat hardened and spiney at the extremity. In many cases, the flag has a peculiar constriction about an inch or so below the tip, whereas, in a few cases, it has been observed to get twisted and thrown into two or three curls. In some cases, the leaves show a slight tendency to roll when the sun is strong. The exact significance of some of these characters is yet unknown, though the last two may be devices for shunning the strong light and attendant heat.

The hairiness on the leaves. This serves as a diagnostic character of the different strains, but it has to be examined at a particular stage of the plant. At an early stage the hairs are not fully developed, while at a very late stage they fall off. They can be seen well about the middle of August, that is to say, when the plants are 65 to 70 days old. When present normally, they are more numerous on the upper surface of the leaf than on the lower. Some types of the *Kolamba* variety are absolutely or practically glabrous in their leaves, but in others, the leaves are sparsely and in still others more or less thickly covered with hairs. In leaves which are very thickly hairy, the lower surface is also hairy to a certain extent. The hairs may be short and downy or long and coarse. Occasionally, there is a mixture

of both types together. It is very often found that the markedly hairy types are also rather coarse-grained.

The peduncle. This is the uppermost internode of the plant supporting the panicle and is the longest of all. The major part of it remains covered up by the sheath of the flag. But, for convenience, that part of it which emerges above the leaf joint is called the peduncle proper. Its length is a strain character, though it is liable to fluctuate under different conditions. In rich fields there is a good deal of leaf growth and hence the length of the peduncle or its emergence above the sheath appears less, while in poor fields the leaf growth is less and the exposure of the peduncle is greater. In years of poor crop growth also, the emergence is more appreciable than in years of good growth. Similarly the successive tillers in a plant show a greater emergence of the peduncle as the later tillers are obviously weaker than the main, and have shorter sheaths. The range of variation in the length of the peduncle is 1·2 cm. to 12 cm. It is not desirable to have a very long peduncle, as it is likely to break and so to prevent the proper development of the grains.

Reproductive Characters.

Dates of flowering. The dates of flowering in the different strains of *Kolamba* rice range over a period of about 45 to 50 days. This long range is of great practical importance from the point of view of the moisture conditions of different fields and of the even distribution of the available labour. The earliest types flower by about the beginning of September if sown in the first or second week of June, that is to say, in about 80 days from sowing, while the latest types take as much as 130 days, flowering about the middle of October or even slightly later. This range of abont 40 to 50 days can be roughly divided into five periods of flowering. The first of th se ends about September 6th and covers just a few types only. The second period ends by about September 22nd and is not much bigger in the number of types it covers. The third period may be taken to end with the month of September and includes a larger number of types. The fourth period ends with the first week of October and covers the largest number of types in the variety. The fifth and the last period is an insignificant one including only a very few types. These five periods may be called respectively very early, early, medium, late and very late, and may be shown in a tabular form as below :—

Name of period	Range of the period	Days from sowing	Types contained
Very early . .	25th August to 5th September	80—90	A few.
Early . . .	6th September to 20th September	90—105	A small number.
Medium . . .	21st September to 30th September	105—115	A considerable number.
Late . . .	1st October to 7th October	115—122	A very large number.
Very late .	8th October to 15th October	122—130	A few.

This classification is made by taking June 6th as the date of sowing when generally the first showers are received, and is based on the mean dates of flowering of the several strains under study. In line cultures an individual plant was considered to have flowered when the top portion of its panicle emerged above the sheath. In the course of the last five or six years, the strains have flowered at almost a fixed date with very slight seasonal variations, although the time of sowing may have varied by about a week or so. Even such a delay in sowing, as of two months in the case of a late strain, put off the flowering date at the most by about a week and made almost no difference in the date of harvesting although the crop was a very poor one.

The period for which the plants in a single culture (generally exceeding 200 plants in our work) continue to flower is generally longer for the early strains and much shorter for the late ones, probably because when the early strains flower in September, there is much moisture in the soil, the air is more humid and the sun's heat also is not so strong as it is in October when the late strains flower. The maximum shade temperatures during the first week of September and the first week of October actually recorded were 92°F. and 97°F. respectively.

The date of flowering of a plant in a culture is a pretty reliable indication of the purity of the culture if it does not go beyond the normal range. Any unusual extension of this range on any side may be looked upon with suspicion, and in such cases it is generally possible to find confirmatory evidence about the impurity of the culture in the matter of some other characters also. Thus it often helps in roguing an ordinary field sown with a pure type.

The period between flowering and ripening is also a fairly constant one, being about four weeks for the early strains and three weeks for the late ones.

As already mentioned the practical utility of the various strains of *Kolamba* flowering over such a long period is very great. It makes the variety suitable for the varying nature of the soil, the varying nature of the water supply, and the cultivator's need of evenly distributing the available labour for transplanting and harvesting, and the cultivator takes full advantage of it by growing strains with different periods of flowering in different kinds of fields.

Pollination. The study of pollination in the rice plant and in particular in the *Kolamba* variety in the North Konkan may be taken up next. It may enable us to make a proper estimate of the chances of maintaining the purity of a type under field conditions. In rice generally, and in the *Kolamba* variety also, self-pollination seems to be the general rule, though occasional cases of natural cross pollination are also met with. The percentage of natural cross-pollination, however, does not seem to be very appreciable, only about two to four per cent. of its occurrence being noted.[1]

[1] Parnell, F. R. Rangaswami Iyengar, G. N.; and Ramiah, K. The inheritance of characters in rice. *Mem. Dept Agri. India, Bot. Ser.*, Vol. V, No. 7

Hector, G. P Notes on pollination and cross-pollination in the common rice plant, *Oryza sativa*. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. VI, No. I.

Researches with the rice plant, Van der Stock in Java.

In a rice plant which is about to flower, the panicles from the successive tillers are not all at the same height, nor are they all ready to flower the same day. The taller and the more central tillers being more advanced are the first to flower. In the individual panicle the flowering proceeds from above downwards. (Pl. II, 2) A few of the topmost spikelets on the branches open first, the lower ones and those on the lower branches opening daily in gradual succession. Though some irregularity in this respect may be noticed here and there, still the general order is not much interfered with.

As a general rule, a panicle takes about five to seven days to finish the opening of the flowers from top to bottom according to the prevailing weather conditions and the nature of the strain, such as early or late. At Karjat, the opening of the glumes generally takes place from 9-30 to 11-30 A.M. Most vigorous flowering is seen between 10 and 11 A.M. A few stray cases may be seen as late as 12 noon. Sometimes, if the day is a rainy one and the temperature lower than usual in the morning, flowering may continue up to 2 P.M. Late in October when the days are particularly warm, the flowering may take place once more in the evening between 4-30 and 5-30 P.M., but such cases are almost negligible.

The glumes take about seven to eight minutes to open fully from the time they begin to show the least sign of parting. When fully open they make an angle of 30-35 degrees with each other. They remain open for about 45 to 50 minutes and then close up within about five minutes or so. The entire period from the beginning of the opening to the closing of the glumes occupies about 55 to 60 minutes. The temperatures at which flowering takes place range from 80°F. to 95°F., the optimum being 85°F. for the early varieties and 90°F. for the late ones.

In the course of the flowering period during a single day the flowering is in certain waves so that there are moments when several flowers on a panicle may open at once, then a few more after a short while, and again a few more and so on.

In the earliest opening flowers, the anthers generally emerge from the glumes and hang down quite intact for a time, the stigmas remaining quite uncovered with pollen. Then after a time which may extend occasionally even to five minutes or so, they burst and shed the pollen outside the glumes. In some cases, one or two of the anthers may remain held inside the glumes ; they may then burst inside and pollinate the stigmas.

As the temperature rises with the advance of the day, the anthers burst while emerging from the glumes or even while they are inside, thus covering the respective stigmas quite fully.

It may be supposed that, as a general rule, the stigma is receptive by the time the glumes open, because, leaving aside the earliest opening flowers, the stigmas in the glumes opening in our presence are more or less covered with pollen. This shows that the stigmas and pollen are both in a fit condition at the normal time of the opening of the flowers.

It has been observed in some cases that the two stigmas spread out so that they protrude beyond the margin of the flowering glume and pale, and when these close up, they are caught up between their overlapping edges. It is suspected that this may happen if for some reason or other the stigmas are not self pollinated. They can often be seen then as brownish specks on either side of the spikelets when the spikelets are mature. Such an exposed condition of the stigmas may occasionally be helpful in bringing about cross pollination either through wind or through insects. In connection with the possibility of insect agency, it has been noticed that Cantharid blister beetles and bees commonly visit the rice flowers during the hours of flowering.

In the period of flowering, especially of the late types, there is generally no rain ; but the wind is often strong, and it must be a powerful agent in bringing about cross-pollination at least in a few of the flowers in which the stigmas may remain exposed as stated above, especially if the crop is of a heterogeneous nature. In fact, when the anthers are bursting, the slightest jerk is enough to show tiny clouds of pollen grains wafted by the wind to the nearest panicle. A large number of blister beetles of two or three kinds are also seen busily engaged in feeding on the anthers, most of which are already quite or partially emptied of their pollen. The abdominal parts of these insects and their legs etc. are covered with hair to which the pollen is seen to adhere. Similarly, small bees and thrips are also occasionally seen to visit the rice flowers. So, all things taken together, with the exposed condition of the stigmas in certain cases, might easily explain the occasional cross-pollination [1] which takes place in rice. Besides we may also have to take into consideration (in some cases at least) the prepotency [2] of foreign pollen, even supposing that in many cases in which the stigmas remain exposed, self-pollination may have been effected.

The panicle. The panicle in the different strains of *Kolamba* rice shows considerable variation under the following heads :—(1) length, (2) number of branches, (3) total number of spikelets, (4) density, (5) sterility, (6) nature when ripe and (7) yield or weight of grain.

Length of panicle. It is usual to measure the length of the panicle from its lowest node which is generally hairy to the tip of the main axis. The length of the panicle in the different strains so measured varies on an average from 22 cm. to 29 cm. It may be said in general that in accordance with the nature and stature of the plant, such as short or tall, the panicle may be short or long. The branches of the panicle also may be short or long according as the panicle is short or long.

Number of Branches. The number of primary branches of the panicle varied in our cultures from 10 to 14·9. Curiously enough, long panicled types have pro-

[1] Hector G. P. Notes on pollination and cross pollination in the common rice plant, *Oryza sativa*. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. VI, No. 1. F. R. Parnell, G. N. Rangaswami Iyengar and K. Ramiah. The inheritance of characters in rice. *Mem. Dept. Agri. India, Bot. Ser.*, Vol. V, No. 7.

[2] Darwin and modern science, by A. C. Seward.

portionately fewer branches, whereas the short panicled types have a comparatively larger number. Consequently, longer panicles are somewhat sparser in appearance, whereas the shorter ones are denser or more compact. But in this respect the total number of spikelets borne by the panicle or in fact by an individual branch is also greatly responsible, because both in the case of the number of branches and also in the case of the number of spikelets, the larger the number per unit length, the greater the compactness becomes evident.

Occasionally the tips of the panicle branches show certain peculiarities, and although they are not of any great significance still they may be mentioned here in passing. (1) In that portion of a panicle where there is no sterility due to the presence of rudimentary spikelets, two spikelets at the end of a branch are placed much closer together than the lower ones, giving the appearance of what may be called tip clusters. This character is found commonly in many of the *Kolamba* types with compact heads. (2) In a few cases, the spikelets in a panicle and especially those near the tip of the branch are more or less strongly curved or hooked at the tip. It is suspected that this character has some relationship to sterility, since in a few perfectly sterile (Pl. IV, 1) plants which have been noticed such hooking at the tips of the spikelets was noticed to a marked degree.

Total number of spikelets. This has been ascertained by actually counting all the spikelets in the ripe main panicle including the fertile, the half developed and the unfilled or chaffy. The total number in the different strains varies from 253 to 575 on an average. Though it is desirable to have a very large number of spikelets in a panicle, still it has been found, as a general rule, that the large number of spikelets is associated with considerable sterility. It is also associated with fineness of grain and poor to medium tillering. So the grain yield of a panicle, or even the whole plant for that matter, is not necessarily proportionate to the number of spikelets borne by the panicle.

Density of the panicle. Strictly speaking, the density or compactness of the panicle depends on (1) the length of the panicle, (2) the number of branches borne on the main axis, (3) the length of the flower bearing part of the individual branch and (4) the total number of spikelets in the panicle. In other words, density is an expression of the combined result of the four factors mentioned above. This expression is, however, very difficult to arrive at except in a very laborious way in practice and therefore it was considered very desirable to get an expression of density by dividing the total number of spikelets in the panicle by the length of the panicle only. Measured in this somewhat arbitrary way, the density of the main panicle in the different strains was found to vary from 9·2 to 22·3. It may be pointed out here that the main panicle or the one borne by the mother culm in a plant being generally the largest of all, carries the largest number of spikelets and is also the densest and heaviest, those borne by the successive tillers being smaller,

Jacobson, H. O. Correlative characters of the rice plant. *Philippine Agri. Review,* Vol. IX, page 118.

PLATE III.

Showing on the left, Sterility at top of the panicle; on the right, no sterility at top of the panicle,

sparser and lighter in comparison. Some degree of positive correlation seems to exist between the density and sterility, so that the denser the panicle the more sterility it has.

Sterility in the panicle. Sterility or the habit of producing unproductive spikelets is a phenomenon of a rather common occurrence in some rice varieties and in *Kolamba* in particular. It may be inborn or incidental and due respectively to internal or external causes. As a result, there is either a complete lack of fertilisation or an interference with the further development of the ovule, the economic loss in either case being practically the same. Instances of the first kind can be seen in several types of the *Kolamba* rice in which a smaller or larger portion at the top of the panicle is occupied by rudimentary and undeveloped spikelets which are quite white and papery in appearance and do not produce any grains. These colourless or rudimentary spikelets can be seen only while the panicle has just emerged from the sheath or for three or four days after. But later on when the panicle ripens, they dry up and fall off. Similar rudimentary spikelets are also found sometimes at the base of the lower branches in certain types of *Kolamba*. A very similar result is often produced in fields which receive large quantities of manurial washings as near village sites. This kind of sterility is known as sponginess in Java. It is evident that in the case of such rudimentary spikelets both the pollen and the ovary are more or less aborted. Occasionally, certain plants are found in which there is absolutely no grain-formation. They remain green long after their brothers have dried up, and show complete lack of self fertilization in their panicles. The spikelets are nearly normal in form and texture though slightly reduced in size. This want of grain formation has been found to be due to the impotency of the anthers,[1] since the pollen grains which they contain are quite deflated and devoid of contents. In such plants occasionally a grain or two may be formed, but it is probably due to the cross pollination from normal plants. In a few cases, attempts had been made to cross such flowers artificially, but the attempts were not successful.

Instances of the second kind of sterility are those in which the panicles remain unfilled and feathery owing to the attack of stem borers or of sclerotial disease. In these cases, the supply of nutrition is cut off and the whole panicle dries up without producing well developed grains.

Occasionally only stray spikelets in a panicle which are quite normal in appearance remain undeveloped due probably to chance lack of fertilization or to unfavourable weather conditions interfering with the act of fertilization, such as heavy rain or very strong sun and winds during flowering. The first condition may either wash the pollen off or cause it to degenerate and the second may dry the pollen up before it is able to germinate on the stigma. It is suspected that, in some such

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[1] Bhide, R. K. A cause of sterility in rice flowers. *The Agricultural Journal of India*, Vol. XVII, p. 584 (1922).

cases also, this partial sterility may be due to the impotency of the anthers in some of the spikelets, but the matter needs further confirmation.

Regarding this sterility of the normal looking spikelets interspersed in the panicle just described, it was observed that in the F_2 generation of certain crosses, a few plants showed that the stamens from a good many spikelets emerged by the normal elongation or their filaments, but the anthers, though quite yellow and outwardly normal looking, did not burst. Most of them appeared to remain yellow and unburst till they dried up. The stigmas from such spikelets were generally uncovered with pollen. On opening such anthers under the dissecting microscope they looked somewhat moist and their contents did not separate into a floury dust. Thus even in this case, the failure seems to be due to the defective condition of the pollen in some spikelets. It could not have been due to want of sunshine, low temperature, etc., since all plants did not show it nor did several other strains show it. In all normal cases, the anthers generally burst while emerging, or just after emergence and assume a whitish colour on shedding their pollen.

In certain cases, some of the lower spikelets in a panicle contain only partially developed grains. This is due to the fact that they are fertilized latest of all, and hence, they cannot get enough time for grain development. Although there is no question here of sterility, still as this condition amounts in effect to practically the same thing, it has been thought desirable to include it here.

Sterility due to sponginess, that is to say, the rudimentary condition of the spikelets is generally associated with types having short compact panicles and short fine grain in *Kolamba* rice. The more compact the panicle the more sterility it has. In such a plant the main panicle again shows more sterility than the later formed panicles as they are smaller and less compact. This kind of sterility due to " sponginess " is rarely found in types which have long and sparse panicles and coarse grains.

Sterility or unproductiveness due to physical or physiological interference with fertilization or partial development of grains can however be found in both types.

In the plant to plant measurements it is difficult to assign exact numerical values to the kind of sterility which is due to sponginess or to the presence of rudimentary spikelets, since they soon fall off. Nothing can, therefore, be made out of such sterility beyond noting the degree of its extent. But it is possible to assign values to the other kind in which the unfilled spikelets can be counted. The percentage of such unfilled or half filled to the well filled spikelets varies from 11 to 42 per cent. in the different strains.

From the breeder's point of view, sterility or sponginess is a very undesirable character. It means so much loss of grain which should have been normally developed. It is, therefore, essential to try and avoid it as far as possible. Unfortunately, there seem to be no fine grained types of *Kolamba* rice which may be said to be absolutely free from sterility.

Dimensions of the spikelets. The average length and breadth of the spikelets in the different strains of *Kolamba* vary from 7·57 to 9·51 mm. and 2·15 to 2·60 mm.

respectively according to the fineness or coarseness of the spikelets. In this connection it may be noted that apart from the length of the spikelet within certain limits it is the thinness which determines its fineness.

The weight of the spikelets. In order to get an idea of the average weight of the spikelets in the various strains, the average number of spikelets required to weigh a gram was found out for the various strains. This number varies from 45·5 to 83 respectively according to the coarseness or fineness of the spikelets. The proportion of husk to clean rice in a given quantity of clean paddy is about 1 to 4.

The nature of the ripe panicle. The panicle, as it emerges from the sheath, is somewhat cylindrical and tapering at both ends. In the course of flowering, the individual branches separate more or less in the different strains and begin to spread away from the axis. As the grain development proceeds, the branches spread out and give the inflorescence the appearance of an open panicle. But when the ripening advances and the spikelets are heavy, the upper part of the panicle droops down in the form of a scythe with the branches closing upon it. In certain cases, the branches do not close on each other though the top portion may droop, and then the panicle looks partly bent down with the branches spread out. In yet another kind which is of rare occurrence, the branches droop down, but the top being comparatively light stands erect. On the whole, the appearance of the mature panicle is dependent on the following factors :—

(1) The length of the panicle.
(2) The number of branches in the panicle.
(3) The length of individual branches.
(4) The number of mature grains on a branch and their fineness or coarseness.
(5) Emptiness or otherwise of the branches at their base.

As a result of the combination of one or more of these factors, the panicles show several types, four of which may be chiefly mentioned.

No. 1. Long and sparse type. In this type the panicle is long, the branches are long and few, the number of grains is comparatively smaller and their size coarser. The panicle when ripe droops almost near the middle. Such are strains 79 and 121.

No. 2. Long and rather compact type. In this type the panicle is medium in length, the number of branches is greater than in type 1. The length of the branches is slightly reduced, the grain size is medium and the panicle when ripe droops a little above the middle. Such are strains 164 and 8.

No. 3. Short and compact type. In this type the panicle length is more reduced than in the above, the number of branches is larger as compared with the length of the panicle, the grains are more numerous and fine. The branches do not droop nor open much but remain somewhat closer together and the appearance of the panicle is compact. Such are strains 39, 35 and 32.

No. 4. Short open type. In this type the panicle is short, the number of branches is medium, the grain is rather coarse, and the branches are somewhat

spreading. The ripe panicle consequently assumes an open appearance. Such is strain 153 or 42. The different types are illustrated in Plate IV, 2.

The yield of a panicle. It may be noted that plants with greater tillering have generally lighter panicles. Secondly, the yield of grain to be obtained from an average panicle depends on the average number of fertile grains borne on it, and the average weight of the individual grains. It has been already mentioned that those types in which the number of spikelets is very large are generally fine grained and show greater sterility on the whole. Consequently, the yield of grain to be obtained from a panicle of such a type is not necessarily very large in proportion to the number of spikelets. Because what is gained in number may not be much more than what is lost in weight. All the panicles again which a plant produces are not of equal size and weight. Efforts were made, therefore, to get an approximate idea of the average yield of a panicle. This was obtained by dividing the average yield per plant by the average number of bearing tillers. Thus the range of yield per average panicle in the different strains is 2·53 to 4·55 grams. When related to the size of the main panicle, the average panicle is found to be from 71 to 80 per cent. It may further be mentioned that it is not the length which so greatly falls in the successive panicles of a plant as the number of branches, the number of spikelets borne on them and the density.

In the various pure strains of *Kolamba* rice which have been isolated by the authors, the correlation between the number of tillers and the yield of grain per average panicle has been found to be negative, though not by any means to the same extent. These results may be summarized in the following Table :—

Showing correlation between number of fertile tillers and weight of an average panicle.

Strain No.	Year	Mean number of fertile tillers	Mean weight of average panicle grams	Co-efficient of correlation between tillering and yield per average panicle	Remarks
79	1923	3·08	3·84	—0·32±0·04	Coarse grained.
184	,,	3·56	2·53	—0·34±0·04	Medium grained.
153	,,	8·62	2·73	—0·19±0·04	Ditto.
164	,,	6·72	3·42	—0·05±0·04	Rather coarse grained.
32	,,	7·40	3·29	—0·15±0·04	Fine grained.
35	,,	6·25	4·07	—0·40±0·04	Ditto
42	1922	9·53	3·51	—0·24±0·04	Fairly fine grained.

1. Showing panicles which are completely sterile. Total sterility in *Kolamba* 34.

2. Showing four types of panicle. (1) Upper left—Long and sparse type ; (2) Upper right—long and rather compact type; (3) Lower right—Short and compact type ; (4) Lower left—Short open type.

PLATE IV.

Showing correlation between number of fertile tillers and weight of an average panicle.—contd.

Strain No.	Year	Mean number of fertile tillers	Mean weight of average panicle grams	Co-efficient of correlation between tillering and yield per average panicle	Remarks
42	1923	9·48	3·17	—0·15±0·04	Fairly fine grained.
121	1922	7·74	4·55	—0·19±0·04	Coarse grained.
104	,,	11·66	2·94	—0·06±0·05	Medium to coarse grained.
104	1923	9·71	2·74	—0·04±0·04	Ditto.

From this it will be seen that within each pure strain there is in general a negative correlation between the number of fertile tillers and the yield of an average panicle. The amount of correlation appears to vary much. In some strains, as for instance Nos. 164 and 104, it hardly exists. In others, it is distinct, as for instance Nos. 35, 184 and 79.

As between different strains also the relationship between tillering capacity and the yield of the average panicle seems to be distinctly negative, as is seen in the following Table.

Showing correlation between mean tillering and mean weight of average panicle in different strains.

Mean weight of average panicle grams	Mean tillering per plant	Co-efficient of correlation	Remarks
4·6	7·06	—0·39±0·09	Correlation appreciable.

The yield per plant. The yield per plant is of the utmost economic importance and depends, as will be seen from the above, on the combination of the yield of the average panicle and the effective tillering capacity of the plant. These characters are probably somewhat antagonistic in *Kolamba* rice. But a type with a fairly high tillering capacity and a moderately large and heavy panicle is likely to give the highest yield.

The relationship of tillering to yielding capacity per plant in a pure strain which is of a positive nature has been determined for a number of strains in 1923, a culture containing about 240 plants in each case forming the basis of the study.

The results are as follows :—

Showing correlation between tillering and yield per plant.

Strain No.	Mean number of fertile tillers	Mean yield of grain per plant grams	Co-efficient of correlation between tillering and yield per plant
79	4·1	11·7	0·71±0·02
184	3·6	8·9	0·80±0·001
153	8·6	23·4	0·67±0·02
164	6·7	23·0	0·72±0·02
32	7·4	24·1	0·75±0·02
35	7·2	25·2	072±0·02
42	9·5	29·8	0·64±0·02
121	7·7	35·9	....
104	9·7	26·5	0·84±0·02

It will be seen from these figures what a close relationship *within a strain* there is between number of tillers and the yield per plant. This is perhaps what might have been expected as the size of the earhead should vary little within a pure strain. Between different strains also the correlation is close, though not always so. The following tables are enough to show clearly that among strains of *Kolamba* rice, at any rate, yield is determined more by the number of fertile tillers than by any other factor, except perhaps the height of the plant :—

Correlation between tillering and yield per plant in different strains in different years.

Strain	Mean No. of fertile tillers	Mean yield per plant Grams	Co-efficient of correlation	Remarks
Reserve Kolamba strains 1923.	5·30	13·93	0·38±·05	The strains were widely different in period of flowering, grain size, No. of grains per panicle, weight of panicle, and yield per plant. The total observations were 138.
New panicle series, 1924	5·39	14·97	0·67±·02	The strains were more alike. These were 180 and 125 observations respectively.
New panicle series, 1925	6·21	18·81	0·64±·03	
Bulk Selection series, 1925.	5·64	16·42	0·62±·04	The strains were not so nearly alike as above. 87 observations.
Intensive cultures of different years.	8·10	27·15	0·77±·04	The strains were different from each other 39 observations.

In almost all these cases the correlation is close.

Correlation between mean height of plant and mean yield per plant in the intensive cultures.

Strain	Mean height cm.	Mean yield per plant Grams	Co-efficient of correlation	Remarks
Intensive cultures of different years.	142·18	27·08	0·47±·08	39 observations. Correlation fairly close.

Correlation between the height and yield per plant in two strains in 1925.

Strain	Height in cm.	Yield per plant in grams	Co-efficient of correlation	Remarks
42	156·7	36·00	0·54±0·04	Correlation fairly close.
241	143·8	22·02	0·43±0·05	

While dealing with these correlations, it will be interesting to indicate some others which have been investigated in 1921, 1922 and 1923 *within two of the pure strains isolated, viz.*, Nos. 79 and 42, the former an early and coarse grained type with low yield, and the latter a late type with finer grain and high yield.

The results are as follows :—

I. Correlation between tillering and the length of the main panicle.

Strain No.	Mean No. of tillers	Mean length of panicle cm.	Co-efficient of correlation between tillering and length of panicle	Remarks
79 (1921) . . .	8·5	26·7	0·11±0·04	Correlation slight.
79 (1922) . . .	5·0	27·5	0·11±0·04	
42 (1922) . . .	10·0	24·8	0·22±0·04	Correlation rather appreciable.

II. Correlation between tillering and number of spikelets in the main panicle.

Strain	Mean No. of tillers	Mean of No. of spikelets	Co-efficient of correlation between tillering and spikelets	Remarks
79 (1922) . . .	6·0	274·0	0·35±·04	Correlation appreciable.
42 (1922) . . .	10·0	419·2	0·07±·04	Correlation negligible.

III. Correlation between tillering and number of branches in the main panicle.

Strain	Mean No. of tillers	Mean No. of branches	Co-efficient of correlation between tillering and spikelets	Remarks
42 (1922) . . .	10·0	12·3	0·17±·04	Correlation slight.

IV. Correlation between number of branches and number of spikelets in the main panicle.

Strain	Mean No. of branches	Mean No. of spikelets	Co-efficient of correlation between branches and spikelets	Remarks
42 (1922) . . .	12·31	419·24	0·39±·03	Correlation appreciable.

Correlation between the length of the main panicle and the height of the plant in Strain No. 42 in 1922.

Mean length of panicle in cm.	Mean height of plant in cm.	Co-efficient of correlation	Remarks
24·83	133·71	0·21±0·03	Correlation rather appreciable.

The following correlations were also worked out in the different strains in different years :—

I. Correlation between density and number of sterile spikelets in the main panicle in the different strains in different years.

Cultures	Mean density	Mean No. of sterile spikelets	Co-efficient of correlation	Remarks
Intensive cultures of different years.	16·18	88·60	0·63±0·07	33 observations. Correlation close.

II. Correlation between density and sterility percentage in different strains in different years.

Cultures	Mean density	Mean sterility percentage	Co-efficient of correlation	Remarks
Intensive cultures of different years.	16·18	19·70	0·29±0·10	33 observations. Correlation appreciable.

III. Correlation between number of grains per gram and sterility percentage in different strains in different years.

Cultures	Mean No. of grains per gram	Mean sterility percentage	Co-efficient of correlation	Remarks
Intensive cultures of different years.	69·22	19·70	0·16±0·11	32 observations. Correlation slight.

Thus it will be seen from the above results that there is a close correlation between density and number of sterile spikelets, and an appreciable one between density and sterility percentage. There is also appreciable correlation between number of branches of the panicle and number of spikelets and between tillering and number of spikelets in the panicle in strain No. 79, though the same in strain No. 42 is negligible. The correlation between length of the panicle and height may be said to be rather appreciable in the case of strain No. 42, but the other correlations worked out seem to be slight or negligible.

Returning to the consideration of the yield per plant, it may be stated that in the very early strains this is generally low, presumably owing to the short period of growth. Further, these very early strains have all a low tillering capacity and

their panicles also are small. Although the grains in these strains may be coarse, their individual weight is not large enough to make up the shortage due to low tillering and the small number of grains per panicle. The yield per plant in the late strains is generally more than in the early strains as will be seen from the following Table :—

Showing the comparative yields per plant in the early and late strains in the year 1923

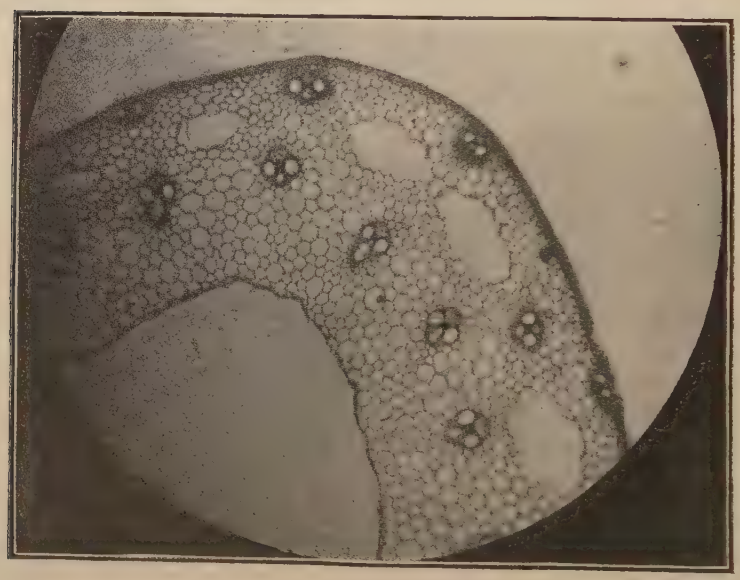
Nature of strain	Strains Nos.	Mean tillering per plant	Mean yield per plant	Remarks
			grams	
Very early . . .	No. 79	4·1	11·7	Coarse grained.
Very early . . .	No. 184	3·6	8·9	Medium grained.
Intermediate . . .	No. 153	8·6	23·4	Medium grained.
Intermediate . . .	No. 164	6·7	23·0	Rather coarse grained.
Late	No. 32	7·4	24·1	Fine grained.
Late	No. 35	7·2	25·2	Fine grained.
Late	No. 42	9·5	29·8	Fairly fine grained.
Late	No. 121	7·7	35·9	Coarse grained.
Very late . . .	No. 104	9·7	26·5	Med. to coarse grained.

So far only the yield of grain has been considered, but the straw is of considerable importance also as it serves as fodder in the tract. The following are the comparative figures of grain and straw yields in the extensive cultures grown in a plot of one-fortieth of an acre each in the year 1924.

Strain No.	Grain weight in lb. from number of bunches of equal size			Straw weight in lb. from number of bunches			Ratio of grain to straw	
							Grain	Straw
	lb.	oz.	Bunches	lb.	oz.	Bunches		
153 . .	69	00	1,629	72	00	1,629	1·000 :	1·044
164 . .	62	08	1,787	72	04	1,787	1·000 :	1·156
32 . .	80	10	1,474	83	00	1,474	1·000 :	1·029
35 . .	89	04	1,734	92	12	1,734	1·000 :	1·039
39 . .	76	08	1,661	83	12	1,661	1·000 :	1·094
42 . .	84	12*	1,248	77	04	1,248	1·095 :	1·000
223 . .	77	14	1,468	73	06	1,468	1·060 :	1·000
104 . .	77	08	1,307	107	06	1,307	1·000 :	1·380

* The low yield of strain No. 42 here is due to thin planting as will be seen from the number of bunches.

PLATE V.



A.—Transverse section of stem of a standing strain. Behind the air cavities lined by single layers of larger cells can be seen bands of sclerenchymatous tissue. These are conspicuous by the very small size of their cells and greater thickness of their walls. These bands are absent in B, the transverse section of a lodging strain.

The above table shows that Nos. 42 and 223 give more grain than straw, while the others give more straw than grain.

Strength of straw. This is rather an important character in determining the utility of a strain of rice. On it depends to a certain extent whether a strain can maintain an erect position or is likely to lodge in the field at maturity. Such lodging at maturity entails not only some loss of grain, but also a reduction in its quality, especially if the fields are very wet. The actual standing or lodging of any strain is influenced by external conditions such as the high fertility of the field and the weather at the time of maturity. If the fields are very richly manured, the stem tissues become softer and more supple and the plants cannot maintain an erect position. They are easily swayed by the wind, the stems spread and bend outwards and the crop lodges. Stormy weather at maturity generally causes the plants to lodge even though they may be strong in straw. But if we leave out of consideration these abnormal external conditions, then such strains as have a short stature, an erect habit of growth, and a thick culm with a certain amount of mechanical tissue in the stem structure which gives the stems more rigidity, are more likely to stand. Plate V, A shows the stem structure which is generally found in strains which are likely to maintain an erect position at maturity. In them there is a thicker band of sclerenchymatous tissue at the periphery of the stem than in the lodging strains, the fibro-vascular bundles are more numerous, and there are particularly a few layers of small sized sclerenchymatous cells behind the air cavities which are generally found in the hollow rice stem owing to its aquatic habit. These layers of small sclerenchymatous cells are more or less continuous with the sclerenchymatous sheaths of the fibro-vascular bundles lying on either side of the air cavities and form arches of mechanical tissue behind them. They are generally absent in the lodging strains (Pl. V, B). In order to see them, it is necessary to examine sections of stems of the various strains taken at a particular point in the first internode or a little below the second node above the ground when the strains are nearing maturity. Associated with the strength of straw is very often found the erectness of the flag which can be noticed even after the crop has begun to ripen.

Susceptibility to the attack of the stem borer. Some strains seem to be particularly liable to the attack of the rice stem borer, *Schoenobius bipunctifer*, so that in such strains we generally find more plants with white unfilled and feathery earheads than in others. Consequently, this character is very undesirable. It is probably due to the tendency of the strain to have very soft stem tissues, as even in the other strains the borer trouble can be noticed if they are grown in very rich fields or under the shade of trees where softness of tissues is particularly encouraged.

Liability to the green or false smut of rice.*—Certain strains especially those which have a short and compact panicle seem to be more liable to this smut than

* Butler, E. J. Fungi and Disease in Plants, page 228.

others in certain seasons, and though the damage caused by it is not very appreciable, still there is no doubt that it is not a very desirable character. The belief of the cultivators, however, is that this disease appears more particularly in a good crop season.

The habit of shedding the grains at maturity. It is true that this habit is never so marked in *Kolamba* rice as in the "Gonag"[1] of the Dharwar-Belgaum Mallad or in wild rice generally, in which the grains fall away as soon as they are mature. In the case of some *Kolamba* strains, a few of the topmost grains only shed if the crop is a little over ripe. It is found that some long and slender grained types show this habit to a slightly greater extent than those with shorter and thicker grains, and consequently the harvesting of such types has to be done before the crop is dead ripe.

IV. Description of selected strains of Kolamba rice.

It is now proposed to give a short description of the eight pure strains of *Kolamba* rice, grown from selfed seed for several generations and which have maintained their uniformity in the characters studied. They do not necessarily represent the whole of the variety; for all were originally selected among others for some valuable character such as high yield, stiff straw, early ripening, etc., and represent the best among the numerous types originally obtained. Of them, one is a very early type, two are early, four belong to the main crop of late types, and one is a very late type.

Strain No. 79. This is the earliest ripening strain found in the mixed *Kolamba* rice seeds obtained from the greater part of the area. It has the fewest tillers and least number of branches in the panicle. The amount of sterility is small, and the density of the panicle is low. The yield per plant is low, and the grain is coarse.

This strain is valuable because of its very short period for ripening. It requires about 110 to 115 days from sowing to harvesting. It is, hence, suitable for lands where the water-supply does not last long owing to their high lying character. Though very coarse as *Kolamba* rice, it is finer than the available varieties, other than *Kolamba*, for such soil. It is not superior to such varieties in point of yield, but owing to its finer grain it brings in usually an increased return of about Rs. 10 per acre. The colour of husk is deep brownish yellow and the kernel is also slightly tinged with amber. But on polishing, it becomes quite white and flinty.

With a normal sowing date about June 6th, the date of flowering (as taken from 120 to 250 plants) has varied from August 29th (1921) to September 5th to 7th (1923) or from 84 to 92 days. As has already been stated, the strain ripens in 110 to 115 days, that is to say, it needs about 26 to 31 days from flowering to ripening.

The average number of fertile tillers per plant when grown under the conditions of study previously described varied from an 8·4* in 1921, to 5·0 in 1922,

[1] Salimath Gonag: a weed in drilled paddy, *Bombay Department of Agriculture, Bulletin* No. 107 of 1921.

* The spacing in the field in 1921 was wider than in succeeding years.

and to 4·6 in 1923. This difference is not purely seasonal, but shows the extent of variation that may be expected, under varying conditinos of spacing. The general average is just 6·0 tillers per plant. Of this total No. of tillers 7·8, 4·5 and 4·1 have yielded earheads in the three years studied. The proportion has thus been 93 per cent., 90 per cent. and 89 per cent in the three seasons, or a general average of 91 per cent.

The height of the plant has varied from an average of 118½ cm. in 1923 to 133½ cm. in 1921, giving an average height at Karjat of 125 cm. The panicle length has been very constant only varying from 26·3 to 27·5 cm. These figures have, of course, nothing absolute about them, and are only given to enable comparisons to be made with other strains grown under similar conditions.

Details as to the characters of the panicle on the average, are shown in the following Table :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams	Remarks.
1921 . .	10·1	252	9·3	32·9	4·8	Wider spacing.
1922 . .	10·2	247	10·0	65·3	4·2	
1923 . .	9·2	251	9·4	47·7	4·0	
1924 . .	9·7	241	8·4	31·3	3·9	
General average	9·8	255	9·3	44·3	4·2	

The most interesting of these figures is that showing the variation in the proportion of sterile spikelets from season to season on the main panicle. These sterile spikelets amount to 13 per cent. in 1921 and 1924 ; 24 per cent in 1922 ; and 19 per cent. in 1923 ; and indicate the extent to which variations in yield, even in a pure line, may be caused by seasonal conditions.

The above figures deal with the main panicle ; the following show the yields from the main and average panicle, and from the whole plant :—

Year	Yield of main panicle (average)	Yield of average panicle	Yield of whole plant
	gram	gram	gram
1921	4·8	3·2	25·8
1922	4·2	3·4	14·9
1923	4·0	2·8	11·7
1924	3·9	2·5	16·7
General average . .	4·2	3·0	17·3

The character of the spikelets themselves is shown by the following determinations of average length and breadth, while the size is clearly shown by the number of spikelets per gram :—

Year	Average length of spikelet mm.	Average breadth of spikelet mm.	No. of spikelets per gram
1921	9·3	2·40	51
1922	9·3	2·40	49
1923	9·3	2·50	52
1924	9·4	2·40	54
General average	9·3	2·42	51

Strain No. 164.

This is a type, which while ripening later than No. 79, is yet a rather early strain. It has the longest grain (spikelet) among all the selections made in *Kolamba* rice. It is rather strong in the straw, and is suitable for high lands which retain water a little longer than those on which No. 79 would be grown. It is distinctly finer or more slender than that last described, but among *Kolamba* rices it would be classed as rather coarse. It would bring about Rs. 12 to Rs. 15 per acre, normally more than the coarse non-*Kolamba* rices suitable for similar lands. The colour of the husk is a light brownish yellow, and that of the kernel a very light amber. The grains are white and flinty when polished.

With a normal sowing date about June 6th, the date of flowering has varied from September 25th to 28th and the length of time from sowing to flowering from 111 to 114 days. The strain ripens in 135 to 140 days, and then it needs about 24 to 26 days from flowering to ripening.

The average number of fertile tillers per plant when grown under the conditions of growth previously described varied from an average of 7·8 in 1923 to 10·5 in 1922. The general average is 9·2 per plant. Of this total number of tillers 6·7 and 8·1 respectively yielded fertile earheads in the two years of study. The proportion has thus been 86 and 88 per cent. respectively in the two years, or a general average of 87 per cent.

The height of the plant has varied from an average of 140 centimetres in 1923 to 142 cm. in 1922. The panicle length is a very constant feature, only varying

from 27·2 to 27·4 cm. on the average based on a study of main panicle only, as shown in the following Table :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams
1922	13·4	349	12·7	70·8	5·3
1923	12·7	349	12·9	50·5	5·0
1924	13·6	369	13·1	66·0	5·3
General average	13·2	356	12·9	62·4	5·2

The sterile spikelets amounted to 20·3 per cent. of the whole number on the panicle in 1922, while in 1923 and 1924 the corresponding figures were 14·5 and 18 per cent. respectively. It will be seen that in two cases the proportion of sterility is less than in strain No. 79, and the change caused by the differences in season is in the same direction in the two strains.

The above figures deal with the main panicle. The following show the yields from the main and average panicle and from the whole plant :—

Year	Yield of main panicle	Yield of average panicle	Yield of whole plant
	grams	grams	grams
1922	5·3	3·8	30·9
1923	5·0	3·4	23·0
1924	5·3	3·5	25·1
General average	5·2	3·6	26·3

The character of the spikelets themselves is shown by the following determinations of average length and breadth, while the size is clearly shown by the number of spikelets per gram :—

Year	Average length of spikelet mm.	Average breadth of spikelet mm.	No. of spikelets per gram
1922	9·3	2·30	54
1923	9·4	2·40	59
1924	9·4	2·40	56
General average	9·36	2·36	56

Strain No. 153.

Strain No. 153 is one which ripens almost at the same time as that last described, and so may be classed as a rather early strain. It has the shortest panicle length among all the selections made of *Kolamba* rice. It yields well, and is finer and shorter in grain size than No. 164. It is valuable for the same type of land as No. 164, but has a weaker straw than the latter. Owing to its finer grain it brings a higher price than No. 164. The colour and behaviour of the spikelets and grains are very similar to that last described.

With a normal sowing date about June 6th to 10th, the date of flowering has varied from September 25th to 29th ; and the length of time required for flowering is from 111 to 115 days. The strain ripens in 135 to 140 days, and thus it needs from 24 to 25 days from flowering to ripening.

The average number of fertile tillers per plant, when grown under the conditions previously described, varied from an average of 8·7 in 1923 to 11·2 in 1922. The general average is 9·9 per plant. Of the total number of tillers, 8·6 and 10·2 respectively yielded fertile earheads, in the two years of study. The proportion of tillers which are fertile has thus been nearly 99 per cent. in 1923, and 91 per cent. in 1922, or a general average of 95 per cent.

The height of the plant has varied from an average of 137 cm. to 142 cm. The panicle length, which is very short as already noted, varies from an average of 20·6 cm. to 22·0 cm. in the two years under study.

Details as to the characters of the panicle, based on a study of the main panicle only, are as follows :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams
1922	12·9	371	17·9	128·3	3·7
1923	12·0	391	17·7	86·4	4·2
1924	11·0	345	17·1	80·1	3·7
General average . . .	12·0	369	17·6	98·3	3·9

It will be seen that the proportion of sterile spikelets on the main panicle has varied from nearly 38 per cent. in 1922 to about 22 to 23 per cent. in 1923 and 1924. As with other strains the sterility was much less in 1923 than in 1922, but in both years it was considerably greater with this than with the strains previously described.

The above figures deal with the main panicle. The following show the yields from the main and average panicle and from the whole plant :—

Year	Yield of main panicle	Yield of average panicle	Yield of whole plant
	gram	gram	gram
1922	3·7	3·0	30·5
1923	4·2	2·7	23·4
1924	3·7	2·6	22·4
General average . . .	3·9	2·8	25·4

The character of the spikelets themselves is shown by the following determination of average length and breadth, while the size is shown by the number of spikelets per gram.

Year	Average length of spikelet	Average breadth of spikelet	Number of spikelets per gram
	mm.	mm.	
1922	8·2	2·30	66
1923	8·2	2·40	73
1924	8·3	2·30	71
General average . . .	8·23	2·33	70

This shows how much smaller is the grain than in the strains previously considered.

Strain No. 32.

Strain No. 32 is later than those previously considered and belongs to the *late* types. It is one of the selections which have the finest and hence the lightest grain, but it yields well. It is specially valuable as combining fairly good yield and fine quality of grain which fetches a good price in the market. The colour of the husk is pale yellowish brown, and that of the kernel is white. The grain on polishing is quite white and flinty.

With a normal sowing date about 6th to 10th June, the date of flowering has varied from October 4th to 8th ; and the length of time from sowing to flowering from 118 to 122 days. The strain ripens in 145 to 150 days, and thus needs from 25 to 26 days from flowering to ripening.

The average number of fertile tillers per plant when grown under the condition previously described varied from an average of 8·8 in 1923 and 9·7 in 1922 to 14·9 in 1921.* The general average is 11·1 per plant. Of this total number of tillers, 8·4, 9·0 and 14·0 yielded fertile earheads in 1923, 1922 and 1921 respectively. The proportion of tillers which are fertile has thus been 95·5 per cent. in 1923, 92·8 per cent. in 1922, and 94·6 per cent. in 1921, on the general average of 94·3 per cent.

The height of the plant has varied from an average of 137·31 cm. in 1923 and 134·6 cm. in 1922 to 151 cm. in 1921 ; the average height in three different years at Karjat being 141 cm. The panicle length is about average for *Kolamba* rices, and has varied from 22·9 to 25·1 cm. in the four years under study.

Details as to the characters of the panicle, based on a study of the main panicle only, are as follows :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams
1921	12·5	436	17·9	91·5	4·4
1922	13·3	469	18·7	110·9	4·6
1923	13·0	461	20·0	119·3	4·2
1924	12·8	428	16·5	106·3	4·2
General average	12·9	448	18·3	107·0	4·4

It will be seen that the proportion of sterile spikelets on the main panicle has varied between nearly 30 per cent. in 1921, nearly 24 per cent. in 1922, and 25 to 26 per cent. in 1923 and 1924. Unlike the earlier strains, the percentage of sterility was not lower in 1923 than in the previous year.

The above figures deal with the main panicle. The following show the yields from the main and average panicle and from the whole plant.

Year	Yield of main panicle	Yield of average panicle	Yield of whole plant	Remarks
	grm.	grm.	grm.	
1921	4·4	3·1	43·0†	†The number of plants was only 88 or comparatively small and the edge effect considerable.
1922	4·6	3·4	30·6	
1923	4·2	3·3	24·1	
1924	4·2	3·0	28·5	
General average	4·4	3·2	31·5	

* The spacing in the field in 1921 was wider than in succeeding years.

The character of the spikelets themselves is shown by the following determination of average length and breadth, while the size is shown by the number of spikelets per gram.

Year	Average length of spikelet	Average breadth of spikelet	Number of spikelets per gram.
	mm.	mm.	
1921	7·8	2·20	77
1922	7·9	2·20	76
1923	7·8	2·30	81
1924	7·8	2·20	75
General average	7·82	2·22	77

The fineness of the grain even as compared with the fairly fine type No. 153 is well illustrated by these figures.

Strain No. 35.

This strain is similar to that last described as regards time required to produce flowers and to mature. It represents absolutely the finest type in the selections made, and is curious moreover as having the largest number of branches and the largest number of spikelets in the main panicle. But it also shows the highest sterility. The panicle is the densest among the strains isolated. It is a useful strain, as combining a fairly good yield and fine quality of grain. The colour of the husk is light and the grain is white and flinty and polishes well. It seems very liable to the disease known as false smut.

With a normal sowing date about June 6th, the date of flowering has varied from October 4th to 8th ; and the length of time from sowing to flowering from 120 to 124 days. The strain ripens in 145 to 150 days, and thus needs from 25 to 26 days from flowering to ripening.

The average number of fertile tillers per plant when grown under the conditions previously described varied from 7·7 in 1922 and 1923 to 13·1 in 1921.* The general average is 9·5 per plant. Of this total number of tillers 7·2, 7·4 and 12·5 yielded fertile earheads in 1923, 1922, and 1921 respectively. The proportion of tillers which are fertile has thus been 93½ per cent. in 1923, 96 per cent. in 1922, and 95½ per cent. in 1921 on an average of 95 per cent.

The height of the plant has varied from 136 cm.to 148 cm., the average of three years at Karjat being 142 cm. The panicle length has lain between 23·6 cm. and

* The spacing in the field in 1921 was wider than in succeeding years.

25·6 cm. with the average of 24·6 cm., or again about the average for *Kolamba* rices.

Details as to the characters of the panicle, based on a study of the main panicle only, are as follows :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams	Remarks
1921. . .	16·0	588	23·8	140	5·8	Plants few and edge effect considerable.
1922. . .	16·3	575	23·4	148	5·4	
1923. . .	15·2	510	21·6	110	4·9	
1924. . .	14·0	484	18·5	101	4·9	
General average.	15·4	539	21·8	125	5·2	

The proportion of sterile spikelets is high, and has varied from 21·6 per cent. in 1923 to nearly 24 and 25 per cent respectively in 1921 and 1922. In this strain there was a lower percentage in 1923, as with the earlier strains previously described.

The above figures deal with the main panicle ; the following show the yields from the main and *average* panicle and from the whole plant.

Year	Yield of main panicle	Yield of average panicle	Yield of whole plant	Remarks
	grm.	grm.	grm.	
1921	5·8	4·1	51·3*	*The number of plants was only 67 or comparatively small and the edge effect considerable.
1922	5·4	3·9	29·5	
1923	4·9	3·7	25·2	
1924	4·9	3·5	31·1	
General average . .	5·2	3·8	34·3	

The character of the spikelets themselves is shown by the following determination of average length and breadth, while the size is shown by the number of spikelets per gram.

Year	Average length of spikelet	Average breadth of spikelet	Number of spikelets per gram
1921	7·6	2·2	74
1922	7·6	2·1	79
1923	7·5	2·3	83
1924	..	..	78
General average	7·6	2·2	79

PLATE VI.

Showing extensive cultures of strain No. 42 on the left and of strain No. 32 on the right.

These figures show that in fineness this strain is as good as or perhaps a little superior to No. 32, described above.

Strain No. 42.

This strain is of peculiar interest, as it is the one which has proved to be of the greatest practical importance. It is now grown annually on many thousand acres, and the demand for the seed is now keen. Its chief characteristics are its good tillering and heavy yield ; while its grain is *fairly* fine. It has an erect habit of growth, an open panicle, with slight sterility at the top. It has to be noted in connection with this strain that it can be grown in fields which receive large quantities of nitrogenous manures without the fear of running to leaf, at the cost of grain. Consequently, it will bear much higher manuring than most of the other types.

With a normal sowing date about June 6th, the date of flowering has varied from October 4th to 8th, and the length of time from sowing to flowering from 120 to 124 days. The strain ripens in 145 to 150 days, and thus needs from 25 to 26 days from flowering to ripening.

The average number of fertile tillers per plant when grown under the conditions previously described varied from 9·8 in 1923 to 11·6 in 1921. The general average is 10·4 per plant. Of the number of tillers, 95 per cent. bore fertile earheads in 1921, 96 per cent. in 1922, and 97 per cent. in 1923. This gives an average of 96 per cent.

The height of the plant has varied from 134 cm. to 138 cm., the average of the three years at Karjat being 137 cm. The panicle length has lain between 24·2 cm. and 24·8 cm. with an average of 24·5 cm.

Details as to the characters of the panicle, based on a study of the main panicle only, are as follows :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams
1921	11·2	372	15·1	57	4·6
1922	12·3	419	16·8	90	4·9
1923	12·8	407	16·8	70	4·8
1924	12·3	378	14·5	68	4·5
General average . . .	12·1	394	15·8	71	4·7

The proportion of sterile spikelets has varied from $15\frac{1}{2}$ per cent. in 1921 to $21\frac{1}{2}$ per cent. in 1922, and to 17 and 18 per cent. in 1923 and 1924 respectively. The average for the four years is 18 per cent.

The above figures deal with the main panicle ; the following show the *yields* from the main and *average* panicle, and from the whole plant.

Year	Yield of main panicle	Yield of average panicle	Yield of whole plant*	Remarks
	grm.	grm.	grm.	*See Plate VII.
1921	4·6	3·2	35·7	
1922	4·9	3·5	33·3	
1923	4·8	3·2	29·7	This was a poor season.
1924	4·5	3·4	35·9	
General average . .	4·7	3·3	33·6	

The character of the spikelets themselves is shown by the following determinations of their average length and breadth, while the size is shown by the number of spikelets per gram.

Year	Average length of spikelet	Average breadth of spikelet	No. of spikelets per gram
	mm.	mm.	
1921 . . .	8·2	2·3	67
1922	8·1	2·3	68
1923	8·1	2·3	70
1924	..	..	67
General average . . .	8·1	2·3	68

Strain No. 121.

This strain, though it would still be classified as a late or ' main crop ' strain, yet it is about ten days later in maturing than the last three described. It is the tallest of all the selections, has the longest and heaviest panicle and the thickest grains. Unfortunately, though it has been under cultivation since 1920, yet close detailed plant to plant observations were only made in 1922, and hence it is not

YIELD PER PLANT IN GRAMS
IN STRAIN Nº 42 FROM
1921–24.

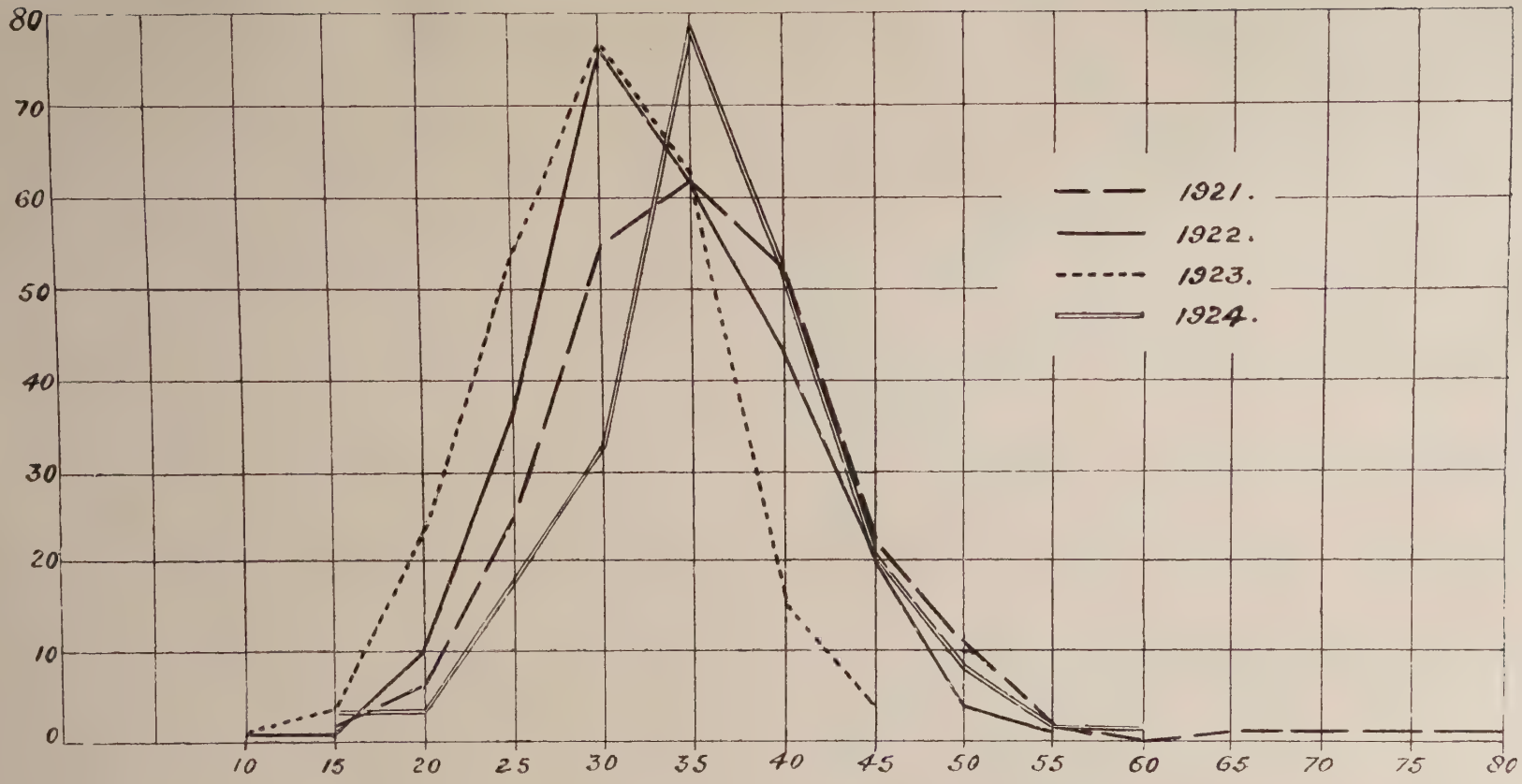


PLATE VII.

possible to compare its characters with complete confidence with the average figures for the other strains. It has only theoretical interest as, though it yields very highly, the grain is too coarse for the market expectation of a *Kolamba* rice.

With June 13 as the sowing date, the date of flowering in 1922 was October 9th to 10th, giving a period of growth to flowering of 118 to 119 days. The strain ripens in 150 to 155 days and thus needs about 30 days or so from flowering to ripening.

The average number of fertile tillers per plant when grown under the conditions previously described was 9·1 per plant, and the fertile earheads numbered 7·7 per plant. This gives a proportion of fertile earheads to total tillers of 85 per cent.

The height of the plant in 1922 under the Karjat conditions was 167 cm. on the average, and the panicle length reached 30·1 cm. Details as to the characters of the panicle, based on a study of the main panicle only, are as follows :—

Main panicle characters. Year 1922.

Number of branches	14·9
Total No. of spikelets	387
Density of panicle	12·7
No. of sterile spikelets	92
Yield of grain	5·8 grams.

The proportion of the sterile spikelets was nearly 24 per cent. in 1922.

The above figures deal with the main panicle ; the following show the yields from the main and average panicle, and from the whole plant in 1922.

Year 1922.

Yield of main panicle	5·8 grams.
Yield of average panicle	4·5 „
Yield of whole plant	35·9 „

The character of the spikelets themselves is shown by the following determinations :—

Year 1922.

Average length of spikelet	8·8 mm
Average breadth of spikelet	2·6 mm.
Number of spikelets per gram	51

These figures illustrate the relative coarseness of the grain in this strain.

Strain No. 104.

Strain No. 104 is the latest of all the selections made and requires about 160 to 165 days from sowing to ripening. It is hence only valuable for low-lying land which retains water until very late in the season. It has a very large number of tillers, the largest in the series,—but on the other hand it has the smallest number

of spikelets on the main panicle which is loose in formation. The sterility is very low. The grain is somewhat coarse, and the straw is strong.

With a normal sowing date about June 6th, the date of flowering has varied from October 17th to 19th, giving a period of growth to flowering of 130 to 135 days. The strain ripens in about 160 to 165 days, so that it requires about 30 days from flowering to ripening.

The average number of fertile tillers per plant, when grown under the conditions previously described, was 10·6 in 1923, and 14·1 in 1922. The general average is thus 12·3 per plant. Of this No. of tillers 9·7 in 1923 and 11·7 in 1922 bore fertile earheads, or a proportion of 91·5 per cent. in 1923 and 83 per cent in 1922. This gives an average of just over 87 per cent.

The height of the plant has varied from 131 cm. to 134 cm. That is to say, its average (132½ cm.) is just about that of the variety. The panicle length has lain between 24·3 and 24·8 cm. with an average at 24·5 cm.

Details as to the character of the panicles, based on a study of the main panicle, are as follows :—

Main panicle characters.

Year	No. of branches	Total No. of spikelets	Density of panicle	No. of sterile spikelets	Yield in grams
1922	15·7	241	9·7	26·2	3·7
1923	11·9	239	9·9	30·5	3·6
1924	12·8	264	10·5	26·7	4·5
General average . . .	13·5	248	10·0	27·8	3·9

The proportion of sterile spikelets has varied from 10·8 per cent. in 1922 to 12·7 per cent. in 1923, and to 10 per cent. in 1924, or a general average of 11·2 per cent. This, it will be noticed, is very low for *Kolamba* rice.

The above figures deal with the main panicle ; the following show the yields from the main and average panicle, and from the whole plant.

Year	Yield of main panicle	Yield of average panicle	Yield of whole plant
	grm.	grm.	grm.
1922	3·7	2·9	34·5
1923	3·6	2·7	26·5
1924	4·5	3·4	36·0
General average . . .	3·9	3·0	32·3

The character of the spikelets themselves is shown by the following determinations of their average length and breadth, while the size is shown by the number of spikelets per gram.

Year	Average length of spikelet	Average breadth of spikelet	Number of spikelets per gram
	mm.	mm.	
1922	8·30	2·40	58
1923	8·60	2·30	58
1924	8·50	2·30	54
General average . . .	8·46	2·33	57

Summary.

It will be seen that, while all the types just described contain the general characters of the *Kolamba* rice, there is a very wide range of variation both in the botanical and in the economic characters. These may now be summarized, basing the results on the general average of each type for the years studied.

I. Plant characters.

Strain No.	Period for ripening grain	No. of fertile* tillers	Proportion of fertile tillers	Height of plant
	days		per cent.	cm.
79	110-115	6·0	91	125
164	135-140	9·2	87	141
153	135-140	9·9	95	139
32	145-150	11·1	94	141
35	145-150	9·5	95	142
42	145-150	10·4	96	137
121	150-155	9·1	85	167
104	165	12·3	87	132

*These averages will have to be slightly reduced to make an allowance for wide spacing in 1921 except in the case of Strains 153, 164, 121 and 104.

II. Panicle characters based on the main panicle.

Strain No.	Length of panicle	Number of branches	Number of spikelets	Percentage of sterility	Density of panicle
	cm.				
79	26·8	9·8	259	19	9·6
164	27·3	13·1	349	17	12·8
153	21·3	12·5	381	30	17·8
32	24·1	12·9	455	27	18·9
35	24·6	15·8	558	24	22·9
42	24·5	12·1	399	18	16·2
121	30·1	14·9	387	24	12·7
104	24·5	13·8	240	12	9·8

III. Spikelet (Grain) characters.

Strain No.	Length of spikelets	Breadth of spikelets	Number of grains per gram
	mm.	mm.	
79	9·3	2·4	51
164	9·3	2·3	56
153	8·2	2·3	70
32	7·8	2·2	78
35	7·6	2·2	79
42	8·1	2·3	68
121	8·8	2·6	51
104	8·4	2·3	58

IV. Yield of grain per panicle and per plant.

Strain No.	Yield of main panicle	Yield of average panicle	Yield per plant	Remarks.
	grm.	grm.	grm.	
79	4·3	3·6	17·5	
164	5·1	3·6	27·0	
153	3·9	2·8	26·9	
32	4·4	3·3	32·6	These figures are high owing to uneven spacing in 1921 and consequent edge effect.
35	5·4	3·9	35·3	
42	4·8	3·3	33·0	
121	5·8	4·5	35·9	Figures available for one year only.
104	3·6	2·8	30·5	

In conclusion, we are much indebted to Dr. H. H. Mann, the Director of Agriculture, Bombay Presidency, for making valuable suggestions in presenting the facts and figures embodied in this paper.

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